Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

CANMET

Canada Centre for Mineral and Energy Technology
Centre canadien de la technologie des minéraux et de l'énergie

# MINING RESEARCH PROJECTS

## (EXCEPT FOR COAL)

## FY 1986-1987

Canada

87-00345/

# MINING RESEARCH PROJECTS

(EXCEPT FOR COAL)

FY 1986-1987

Mining Research Laboratories

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Laboratories at:

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## Foreword

This report contains summaries of all of the research projects which will be undertaken by the staff of the Mining Research Laboratories, of CANMET, Department of Energy, Mines and Resources, during the 1986-1987 fiscal year. The document, which is being introduced this year, is intended to complement the Division's Annual Report and to serve as an additional means of making MRL's research plans known to both the private and public sectors.

The format which is being followed parallels that used by sister Divisions of CANMET. Each project is described by means of statements of objectives, background, and activity planned for the year. To facilitate further contacts the names and telephone numbers of the various project leaders are given.

The work of the Division involves the full-time in-house efforts of a staff of approximately 85 persons. Its mandate includes all mining research except for that devoted to carbons and hydrocarbons. Those are the responsibility of a sister Division, the Coal Research Laboratories, with headquarters in Devon, Alberta.

Apart from their own internal work the staff are also responsible for the supervision and monitoring of a large number of contracted research projects. Largely as the result of the Mineral Development Agreements between the federal and provincial governments the number of such projects has increased rapidly. In dollar terms almost 50% of the funds allocated to the Division will be devoted this year to the contracting of significant parts of the research program out to the private sector. The trend is also towards external large-scale field demonstration type projects. It follows that MRL's contacts with the mining industry are being enhanced considerably.

A list of all of the research contracts in effect for the current year is given as Appendix 'A' to the report.

Inasmuch as the purpose of the document is to facilitate the dissemination of information, responses to it are invited. Either the undersigned or the project leaders listed would be pleased to try to answer questions and to try to provide any further information that may be required.

John E. Udd, Ph.D., P.Eng.,
Director
Mining Research Laboratories
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## Avant-propos

Le présent rapport comprend les résumés de tous les projets de recherche qui seront réalisés au cours de l'annéee financière 1986-1987 par le personnel des Laboratoires de recherche minière du CANMET, Ministère de l'Énergie, des Mines et des Ressources. Le document, qui est publié pour la première fois cette année, servira de complément au Rapport annuel de la Division et de moyen additionnel pour renseigner les secteurs public et privé sur les projets de recherche des LRM.

Le rapport est présenté dans un format semblable à ceux des rapports des autres divisions du CANMET. Chaque projet est présenté par le biais d'exposés sur les objectifs visés, d'historiques et de rapports portant sur les activités annuelles. Les noms et numéros de téléphone des chefs de projets sont également mentionnés dans le but de faciliter les contacts futurs.

Les activités de la Division sont réalisées par un effectif d'environ quatre-vingt cinq personnes qui travaillent à temps plein. Le mandat de la Division englobe tous les projets de recherche à l'exception de ceux qui portent sur le carbone et les hydrocarbures; ces projets relèvent d'une division connexe, soit les Laboratoires de recherche sur le charbon dont le siège social se trouve à Devon (Alberta).

En plus de leurs fonctions au Laboratoire même, les employés doivent également assumer la supervision et le contrôle d'un grand nombre de projets confiés en sous-traitance. Le nombre de ces projets s'est accru très rapidement en raison de l'Entente sur l'exploitation minérale qui a été ratifiée par les gouvernements fédéral et provincial. En termes de dollars, cela signifie que près de 50 % des fonds alloués à la Division seront, cette année, utilisés pour réaliser une grande partie des projets confiés en sous-traitance au secteur privé, dans le cadre du Programme de recherche. Une tendance de plus en plus marquée à réaliser des projets de démonstration sur le terrain de grande envergure se dessine dans le secteur privé. Il s'ensuit une amélioration sensible des contacts des LRM et de l'industrie.

La liste de tous les contrats de recherche qui seront réalisés pendant l'année en cours est présentée à l'Annexe A.

Comme ce document est publié en vue de faciliter la diffusion de l'information, tout commentaire serait très apprécié. À l'instar des autres chefs de projet dont les noms sont mentionnés dans cette présentation, je serais heureux de répondre à vos questions et de vous fournir des renseignements additionnels, le cas échéant.

John E. Udd, Ph.D., ingénieur
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## Certification and Technical Advice

Project Leader R.R. Vandebeek
(613) 996-4570 (X 190)
995-1275

Objective:

To confirm the safety characteristics of all explosives submitted annually for authorization under the Canada Explosives Act.

Background:

All explosive products, including ammunition and fireworks must be authorized under the Canada Explosives Act prior to use in Canada. New explosives submitted for authorization need to be evaluated to assess any peculiar safety hazards related to the product, its manufacture, transportation, storage and use. This testing and evaluation is done at CANMET. Those explosives which do not present unusual hazard are recommended for authorization. In addition, production explosives are monitored on a continuing basis to ensure that prescribed standards are met.

As new types of explosives are developed, i.e., emulsion explosives, new test standards need also to be developed to ensure proper and reliable evaluation of possible hazards before they can be implemented.

Technical advice on explosives and explosion hazards is provided to various government departments and agencies, industry and the public. Accidental explosions are investigated on an 'as required' basis.

New studies are planned to evaluate the potential hazards arising from the use of electric detonators on mine exploration, around radio towers and other communications facilities. An additional thrust will be the study of properties of explosives including detonators and their significance to mining and civil engineering. These properties will include propagation sensitivity and time delay of detonators.

In cooperation with other countries through the United Nations, a Unified International Classification System is being developed to classify explosives for transportation purposes. The Canada Explosives Act will be changed shortly to incorporate this new system. Studies are underway to ensure that no difficulties in classification will arise when the conversion is made.

Planned Activity for 1986/87

a) Testing will be performed on all submitted samples (approximately 350 investigation reports).

b) Technical advice on the manufacture, storage and transportation of explosives will be provided on an 'as required' basis.

c) Investigations of accidental explosions will be on an 'as required' basis.

## Explosives Technology

Project Leader R.R. Vandebeek
(613) 996-4570 (X 190)
995-1275

Objective:

To advance technology related to the manufacture, storage, transportation and use of explosives, specifically, to verify the proposed United Nations classification procedures for incorporation into the Canada Explosives Act and Regulations.

Background:

Explosives Research and Development at CANMET is primarily directed at furthering our technical capability to reduce safety and health risks involved in working with explosives.

CANMET efforts over the past few years have been directed to the development of mathematical models to predict explosives properties and detonation parameters in order to avoid the need for extensive field testing of explosives to determine, for example, the levels of toxic fumes produced on detonation. The work is nearing completion and field verification trials using bulk samples of this R&D. A new fume testing facility is under construction to measure experimentally toxic fumes. Studies are planned to develop a mathematical model to predict the consequence of a vehicle transporting explosives being involved in a collision (low velocity impact). The effects of temperature and fire on explosives during manufacture, storage and transport are being investigated.

Methods to determine properties of explosives are continually being developed or improved as new types of explosives are marketed, in order to contribute risk analysis methodology. New types of explosives are studied in depth to fully characterize them. These include emulsion explosives and explosives based on cured energetic binder technology. New studies are planned to evaluate the potential hazards arising from the use of blasting circuits, i.e., electric detonators, in the vicinity of exploration work, radio towers and communication facilities. An additional thrust will be the study of properties of explosives including detonators on their use in mining and civil engineering projects. These properties will include propagation sensitivity and time delay of detonators.

Planned Activity for 1986/87

a) A final contract report on Low Velocity Impact will be prepared as will a final contract report on High Velocity Impact.

b) A report on the review of the effect of detonator properties on rock fragmentation is in progress.

c) Due at the end of the fiscal year will be a progress report regarding the establishment of a new fume testing facility and initial report on evaluation of detonation products.

d) Currently being prepared is a final contract report on the evaluation of propagation sensitivity of commercial explosives in 15 cm diameter hole.

## Mine Methods and Evaluation

Project Leader J. Pathak
(613) 990-4011

Objective:

To develop and evaluate mineability and mine operational economic criteria, for hardrock mining in Canada, and to prepare biennial estimates of planned and projected production capabilities of uranium mines.

Background:

Technical and economic evaluation of existing and potential uranium mining operations is an essential component of uranium reserve and resource assessment, which has been assigned to CANMET on behalf of EMR Energy Policy Sector. In addition, reliable estimates of uranium production capabilities for individual properties, plus projections of future production, are also required for the EMR Uranium Resource Appraisal Group (URAG). Resulting information on Canadian uranium reserves, resources and production is required as input to policy decisions on domestic and export sales quotas for each projected and operating unit in Canada, as well as the granting of production licences by AECB.

To meet the above commitments, it is essential for CANMET to acquire realistic production cost data to develop adequate mine operations evaluation procedures and to establish a base of unit productivities related to existing and developing mining technologies. Computer techniques will be used where feasible.

The development of such data bases and expertise fortunately is generally applicable to all hardrock mining operations. This will result in a general mine evaluation capability in MRL/CANMET which will be of value to government policy organizations, as well as the Canadian mining industry.

Planned Activity for 1986/87

a) An annual report will be prepared on Canadian uranium production capability, deposit by deposit.

b) Research is underway on the development of computerized mining cost models and mine evaluation procedures.

c) A critical review of mining proposals/feasibility studies will be done on demand.

d) A study will be carried out on the fragmentation optimization for small and medium sized underground mines.

# Advanced Mine Equipment Technology

Project Leader J. Pathak
(613) 990-4011

## Objective:

To assess the potential productive impacts of worldwide developments in new mining equipment and other pertinent advanced technologies, e.g., automation and robotics.

During fiscal year 1986/87, research will be conducted to identify through studies of existing equipment/mining operations and systems, areas where new equipment/equipment systems could significantly affect productivity of mines. And on a continuing basis, to conduct reviews of mine equipment and prepare state-of-the-art reports and to promote the development and demonstration of new mine equipment/equipment systems in all aspects of the mining cycle.

## Background:

The Canadian mining industry is facing its toughest competition from the third world countries and to remain competitive in the international market, it has to find ways and means of improving management, productivity, safety mine environment, equipment availability and utilization and reduce cost, waste, manpower, material requirement and energy.

Successful application of microprocessors, sensors, data transmission, monitoring and control systems in various manufacturing and processing industries have given reasons for its application to underground hardrock mining. There exists considerable potential for transfer of the technology to mine equipment automation, remote control and optimization. The systems will be designed to store all pertinent information regarding performance of the equipment and will also be used for preventive maintenance increasing its availability.

## Planned Activity for 1986/87

a) This fiscal year will bring the development of prototype accessory for down-the-hole drillrig control system.

b) A contract report will be prepared on development and testing of principles of cavitating hydroimpacter.

c) The development of a mine status indicator system (concept 1986) along with the conceptual development of a demonstration project for fully instrumented mine.

## Canadian Mining Technology Coordination

Project Leader J. Pathak
(613) 990-4011

Objective:

To promote cooperation and improve efficiency in the Canadian mining industry, maintaining a national information bank on current and developing mining technology in the mining industry and preparing state-of-the-art reports on mine operational problems.

Background:

Some progressive mine operating companies are, on a continuing basis, collaborating with consulting firms, equipment manufacturers, universities, government research and development, research foundations, etc., to improve and develop the state of the mining technology. Many companies are also involved in in-house research which is aimed at improving their own operation but could be applied to others in Canada. Because their results are generally not published or made known to potential beneficiaries, the technological impact of their research is not felt Canada-wide. To disperse this knowledge, MRL has undertaken to collect information on research/project/activities of these organizations, compile it and distribute it in the mining industry which might be a valuable contribution to mining technology development in Canada.

Planned Activity for 1986/87

a) An annual report indexing all participating organizations, development projects and results achieved is in the preparation stages along with the development of computer data base from the index.

b) State-of-the-art reports on aspects of operational mine technology will be available as required.

## Materials Handling & Operations Research

Project Leader J. Pathak
(613) 990-4011

Objective:

To develop the concepts of optimizing materials handling systems for both underground and open pit mines and to develop mathematical models for calculation of heat transfer in different media and mine segments.

Background:

Since the start of the metals price depression in the early 1980's, the Canadian mining industry has realized that it needs to move ahead of the world mining technology in order to maintain its competitive edge. Besides deployment of reliable and proven equipment, application of mathematical modelling (OR) and computers could optimize utilization of mine equipment, such as truck transportation or trolley-assisted haulage systems in open pit mining, enhancing the productivity. Automation and robotization of trucks in open pits could mean a saving of $150 000 to $200 000 per operating truck.

Other avenues where an impact on time and skilled labour saving could be made is the CAD/CAN equivalent system development for mine design which could also optimize an expensive mine development. The objective of the project will be to increase computer usage and better management information techniques which already exists in the manufacturing and process industry.

Planned Activity for 1986/87

a) A publication is underway on state-of-the-art systems for computerized mine design and operations research.

b) Research is being conducted regarding haulage automation for open pit mine with integration of blending requirements.

## Evaporite Mining Methods

Project Leader J. Pathak
(613) 990-4011

Objective:

To increase potash recovery over current levels by carrying out contract research in the areas of ground control, environmental control and productivity.

Background:

On May 17, 1983, the Minister of Energy, Mines and Resources announced the coming into force of the two-year START Program (Short-Term Aid in Research and Technology) to assist the Canadian mining industry.

One of the thrusts provided for under START covered research and development contracts with short-term industrial benefit. The current recovery rate of Saskatchewan potash is 40% and, though profitable, represents a significant loss of resources as well as profit due in part to increased underground transportation.

A two-year program of contract research under START ($250 000/year) to aid the potash industry has been completed by MRL with the participation of the potash industry. A total of eight contracts which addressed questions of mine design ground control and monitoring of dust were completed. Technology transfer is in progress and two workshops on use of the GEOROCK model for potash mine design is planned for 1986/87.

The two-year program allowed a much needed initiative and the potash industry has responded very well. However, further work is necessary to allow definite suggestions on how to improve recovery. This work is directed towards monitoring excavation behaviour in potash under controlled conditions and further development of numerical modelling capability. (Cominco Potash Mining Operation 1986/1988, IMC 1986/1987, Denison-Potacan 1986/1988.)

Planned Activity for 1986/87

a) A report is being prepared on the monitoring of excavation behaviour at Central Canada Potash and at Cominco.

## Mine and Regional Stability

Project Leader D.G.F. Hedley
(705) 848-2236

Objective:

To evaluate pillar stability on a local and regional scale in Canadian hardrock mines and to determine pre-mining stresses in rockburst-prone mines in mine structures especially around weakness planes.

Background:

CANMET has maintained an extensive program of rock mechanics R&D over the years. The prime thrust of this work in underground hardrock mines has been to improve safety and productivity. Design guidelines have been developed for a number of mining methods and support techniques.

In 1985, a Memorandum of Agreement was signed between Canada/Ontario Mining Industry for a five-year rockburst research project with tripartite funding.

Rockbursts, such as occur in the Canadian pre-Cambrian Shield, are attributed to stress redistributions which accompany mining in hardrock formations. Microseismic activity, which accompanies the stress increase preceeding rockbursts, is viewed as having the potential to locate areas in which rockbursts may occur and, perhaps, to provide a means of short-term prediction prior to occurrence.

Although microseismic systems have been used experimentally in mines for many years, marginal advances in methodology and equipment development have limited their use. This is attributed in part to mine utilization philosophy, staff turnover, and the limited market for equipment which could be developed.

Source location is the objective of the existing, or planned, ten Canadian microseismic systems. The research on rockbursts which is proposed would involve investigation, development and testing of equipment and methodologies directed at improving the location of microseismic build-up, identifying the mechanisms of energy release, and, in some cases, warning of impending rockbursts.

The first two years of the rockburst project are mainly concerned with developing new seismic instrumentation which incorporates wave-form analysis. These systems with other more conventional rock mechanics instrumentation will be tested in mines in Red Lake, Elliot Lake, Kirkland Lake and Sudbury.

In addition to this basic microseismic research, work will continue on measurement and analysis of stress and displacement and computer modelling in hardrock mines.

Planned Activity for 1986/87

a) During this fiscal year, case histories of rockbursts at Elliot Lake, Red Lake and Falconbridge will be produced.

# Rock Mass Characterization

Project Leader M. Bétournay
(613) 995-1147

## Objective:

To evaluate the influence of discontinuities, backfill and other support systems on rock mass stability, especially for surface crown pillars and to address the problem of underground stability where structure and gravitational forces are the major cause of failure. This will be done on two fronts. The first: by producing a handbook on surface crown pillars, including guidelines for design, incorporating applicable knowledge from civil and mining engineering, the second by carrying out field investigations to identify various settings and critical parameters, develop models to predict behaviour, and investigate the effects of various support measures.

## Background:

The Selbaie Mine represents an extreme example of surface crown pillar conditions. Well fractured and highly altered, it represents a challenge to the safe and economical sampling, testing, modelling and monitoring aspects of that surface crown pillar. It will also identify which are the critical parameters to consider for design in such settings.

It is recognized that some specific structures in mining have special stability and support requirements. In these cases, such as for surface crown pillars, special attention is required to delineate the reasons for stability/instability of such structures and the best methods of retrieval of critical parameters, evaluation of stability and support requirements in the context of the operator's mining activity.

When properly included in a valid design approach, rock mass characterization provides the focus for dealing with surface crown pillars. Because of the uniqueness of these mine structures, in a material and comparative sense, such characterization must employ methods and equipment used in the field of mining and civil engineering and would benefit from the availability of a surface crown pillar specific characterization system. Such a system would be applicable to large, multiple openings common in mining and would supply an understanding of how the rock mass interacts with support systems such as backfill.

A multi-year program is underway to develop, with the cooperation of the mining industry, crown pillar design guidelines. The assemblage of a comprehensive set of case histories, a significant component of the guideline will be completed shortly.

## Planned Activity for 1986/87

a) Review of design guidelines for surface crown pillars along with the evaluation of support systems, including backfill, for weak rock masses.

b) A surface crown pillar handbook is being prepared.

## Rock Properties and Support Systems

Project Leader D.G.F. Hedley
(705) 848-2236

Objective:

On a continuing basis, to establish the strength, deformational and other properties of the rock types encountered in research investigations and to evaluate rock mass stability for surface crown pillars.

Background:

Active mining at an increasing number of underground mines involves stress conditions where the post-peak properties of the rock must be taken into account in strata mechanics investigations.

Studies are underway to develop methods and equipment to establish the post-peak strength properties of rock as well as those of rock mass joints under high normal loads.

The performance of a number of artificial support systems under high stress conditions is also being investigated. Research is directed at extending existing design guidelines to mines at greater depth or under greater stress.

Planned Activity for 1986/87

a) A report is in the preparation stages on the joint properties of various rock types.

b) To commission a new servo-controlled rock test system.

c) A review is underway of design guidelines for surface crown pillars.

## Numerical Model Development

Project Leader D.G.F. Hedley
(705) 848-2236

### Objectives:

To conduct studies related to mining applications and to develop guidelines for designing underground openings. Also, to develop numerical models and software packages in forms which are suitable for use with either personal or micro-computers at small mining operations.

### Background:

In mining, the prediction and evaluation of rock mass behaviour is becoming progressively more important in mine design and planning, especially for selecting mining methods, layouts, stope and pillar dimensions, mining sequence as well as for ground control and support requirements. The explicit theoretical solutions are usually not available and perhaps extremely difficult or impossible to obtain because the ground characteristics are always complex.

The complexity is among others depending on geological structural features, rock types and mine geometry. Physical models are proven to be expensive, take time to make, impractical and unreliable. Numerical models are desirable and being accepted as alternative methods for determining stresses and displacements reduce in the rock mass as a result of mining. There is a need to develop and implement numerical models based on the combination of the principles of modern means for predicting ground behaviour of both underground and open pit in a more scientific and rational manner.

### Planned Activity for 1986/87

a) A general purpose finite element program for mine applications will be put into effect.

b) A report is in the works on the stability evaluation for the Detour Lake Mine and Niobec Mine.

c) Implementation of a new version of Dataplot (a graphic and statistical package).

## Underground Nuclear Waste Repository

Project Leader D.G.F. Hedley
(705) 848-2236

Objective:

To determine the thermal-mechanical properties of rocks from study areas in the nuclear waste management programs including anisotropic characteristics. The development of equipment and methods for studying scale effects on shear properties of rock. To establish and to prepare geotechnical program documents in support of concept assessment submissions by AECL.

Background:

Nuclear waste disposal, particularly of spent fuel rods, will become a critical aspect of nuclear electricity generation. CANMET's program is a part of Atomic Energy of Canada Limited's long-term strategy for investigating disposal at depth in stable geological formations. CANMET's geotechnical and mineralogical expertise is required and used to determine how rock behaves under the high temperatures associated with decaying radioactivity.

Planned Activity for 1986/87

a) Progress reports on large scale direct shear test on URL joint block samples and thermal-mechanical rock properties on samples from research areas will be completed this fiscal year.

## Instrumentation Development

Project Leader D.G.F. Hedley
(705) 848-2236

### Objective:

To develop and test field geotechnical instrumentation, specifically, a universal borehole installation tool, a rugged, small, side-viewing borehole T.V. inspection tool and test a stress monitoring unit for boreholes. To provide organizational support for the ISRM Congress in Montreal.

### Background:

A wide variety of instrumentation has been developed over the years but very little objective testing and field evaluation has been carried out. MRL is in the unique position of having mine access and know how to evaluate various types of instrumentation in regards to performance criteria and usefulness. New developments as required for borehole inspection by small diameter T.V. cameras which assist in stability assessments for excavation roofs and evaluation of design assumptions.

In addition, stress monitoring equipment for boreholes needs to be developed. A study is also necessary to identify, for potash mine design, suitable instrumentation for field exploration of deformation modulus and creep data. Brine locations in potash are a major concern in potash mines.

Forcemeters need development and field assessments for stability of readout and usefulness to assess ground vibrations during blasting trials and safety of underground structures in relation to dynamic shock.

### Planned Activity for 1986/87

a) The development and testing of the universal borehole installation tool.

## Manitoba Mineral Development Agreement

Project Leader C.B. Graham
(613) 995-3986

Objective:

To develop Vertical Block Method (VBM) design guidelines; safer procedures for scaling loose rock; a geotechnical database and a numerical package for the design of underground openings at depth; ground stability evaluation criteria for en echelon lensed orebodies; to identify, evaluate and demonstrate the feasibility of using an underground communication system based on existing technology; to develop a new underground mine communications system to meet the specific requirements of the Canadian hardrock mining industry.

Background:

New mining techniques such as vertical blasthole methods create large expanses of hanging wall (and footwall) not found in cut and fill stoping. It is essential to predict how the ground will behave before it is mined. Modelling is the key to relating pre-mined strength and inherent stresses to the post-mined configuration and is predicated on information which details rockmass character. This type of planning allows many 'runs' to test various parameters and their sensitivities.

To properly control the ground, a better understanding of ground behaviour and its response to mining, and the causes of instability, is considered essential. Therefore, studies in the area of rock mass behaviour, mine stability, sophisticated numerical modelling and improved mining technology are planned.

In underground mines, there is also a need for more effective communication systems. Current warning systems of fire hazards, in which stench gas is injected into mine air, are inadequate for working areas which receive limited ventilation. A reliable communication system which permits underground personnel to maintain communications almost anywhere within the mine, and with the surface, will be installed and evaluated.

A communications system for voice and data also completes the requisite infrastructure for automation of underground mobile equipment.

Planned Activity for 1986/87

a) Contracts regarding underground communications systems, underground stability evaluation with particular reference to an en echelon lensed orebody will be completed.

b) The completion of a geotechnical database and a numerical modelling package for the design of underground openings at depth along with the blast design optimisation program and a study on delayed backfill are scheduled.

# Rockburst Research

Project Leader D.G.F. Hedley
(705) 848-2236

## Objectives:

To develop new seismic equipment and monitoring techniques for studying rockbursts in hardrock mines and carry out seismic studies at mines in Sudbury and other Ontario locations. To relate seismic activity to stress displacement and fill pressures at these mines.

## Background:

CANMET has maintained an extensive program of rock mechanics R&D over the years. The prime thrust of this work in underground hardrock mines has been to improve safety and productivity. Design guidelines have been developed for a number of mining methods and support techniques.

Rockbursts, such as occur in the Canadian pre-Cambrian Shield, are attributed to stress redistributions which accompany mining in hardrock formations. Microseismic activity, which accompanies the stress increase preceeding rockbursts, is viewed as having the potential to locate areas in which rockbursts may occur and, perhaps, to provide a means of short-term prediction prior to occurrence.

Although microseismic systems have been used experimentally in mines for many years, marginal advances in methodology and equipment development have limited their use. This is attributed in part to mine utilization philosophy, staff turnover, and the limited market for equipment which could be developed.

Source location is the objective of the existing, or planned, ten Canadian microseismic systems. The research on rockbursts which is proposed would involve investigation, development and testing of equipment and methodologies directed at improving the location of microseismic build-up, identifying the mechanisms of energy release, and, in some cases, warning of impending rockbursts.

The first two years of the rockburst project are mainly concerned with developing new seismic instrumentation which incorporates wave-form analysis. These systems with other more conventional rock mechanics instrumentation will be tested at mines in Red Lake, Kirkland Lake and Sudbury.

In addition to this basic microseismic research work will continue on measurement and analysis of stress and displacement and computer modelling in hardrock mines.

Planned Activity for 1986/87

a) This fiscal year will bring the completion of wave form monitoring at Falconbridge Mine.

b) Also scheduled for completion is the development of an improved micro-seismic monitoring system, with substantial Canadian content.

Special Note:

Participants in this project are Campbell Red Lake Mines Limited, Rio Algom Limited, Denison Mines Limited, INCO Limited, Falconbridge Limited and Lac Minerals Limited.

## Ontario Mineral Development Agreement

Project Leader C.B. Graham
(613) 995-3986

Objective:

To improve productivity and safety in underground hardrock mines by optimizing the support capabilities, placement techniques and engineering design procedures for both sand and rock backfills and to guide the development of multi-purpose software suitable for use on computers at small mines.

Background:

The current directions in Mineral Development Agreement research are based on the amount of backfill used and planned to be used in the industry and on the high cost of present consolidating agents. If modelling, and hence planning, can offer improved stability by determining optimal placement strategies in the mining cycle, and if a detailed investigation of backfill engineering properties can yield cheaper, stiffer backfills then the resultant economies will make more reserves in areas where the development cost has already been paid. At the same time, computing has revolutionized every aspect of engineering and management. The Mineral Development Agreement recognizes the need for a unified direction in program creation by issuing a contract on computer specifications. The industry has been plagued with a myriad of 'solutions' which only run on some very specific hardware and consequently mining industry is being poorly served by software manufacturers. At the other end of the computing spectrum, large programs have seldom been within reach of the mining user and the need is clear because metal economics favours bulk methods and reserves are a depth in established mines. These forces have combined to promote a significant new approach in three dimensional modelling of entire orebodies.

Planned Activity for 1986/87

a) The establishment specifications for computer programs and graphics.

# Ventilation and Respirable Dust

Project Leader J. Bigu
(705) 848-2236

## Objectives:

To design and develop a new dust tunnel at the Elliot Lake Laboratory for studies of airborne particulate contaminants and to carry out studies in uranium mines on dust conditions and ventilation and to determine their relationship to radiation levels. To determine the concentrations of mineral particulates in mine air at various locations and to investigate control measures and demonstrate continuous environmental monitoring systems underground.

## Background:

Dust is a significant factor affecting both the comfort and long-term health of the work force in all mining operations. Dust from certain minerals can lead to lung disease. Lubricating oil mists and diesel exhaust also carry noxious dust and gases. In addition, in uranium mines, dust particulates can carry radon and thoron daughters, and long-lived radionuclides, into the lung and gut where radiation, mostly alpha-particles, emitted internally may give rise to tissue damage.

There is a need to improve measurement techniques, i.e., instrumentation and methods and programs to better assess and predict personal dust exposure. The origin of respirable dust, and its composition and size distribution, among other factors, must be known in order to determine effective control measures and to guide and interpret epidemiological and medical studies. This work requires developing an extensive data base through sampling in mines with improved dust instrumentation. It also requires adequate test and calibration facilities in order to determine the performance, quality and accuracy of dust instrumentation.

Control measure efforts centre on improving breakage and rock handling techniques to minimize dispersion of dust into the air, filtration of airborne dust, wetting techniques, as well as optimizing mine layout and ventilation. Ultimately, optimum control requires appropriate dust suppression and control methods to be built directly into mine equipment and mining methods.

## Planned Activity for 1986/87

a) This fiscal year the commissioning of the new dust tunnel will commence.

b) Discussion document on dust, ventilation and radiation research along with a report on the feasibility of using infra-red analysis (MSL) for silica dust determination will be completed.

## Noise and Vibration

Project Leader R. Tervo
(705) 848-2236

J. Bigu
(705) 848-2236

Objective:

To identify and quantify the major sources of noise and vibration in mines which could present a health hazard to mine workers and the application of technology to reduce such hazard. Specifically, to compare integrating pocket dosimeters, with standard techniques, in a laboratory and in a mining situation.

Background:

In the last ten years Canadian mines have made advances in the field of noise abatement. Measures have been taken to improve protection of miners' hearing by development and use of personal protective devices such as ear plugs and muffs. Some additional work has been done in development of devices to muffle equipment noise output, however, improvements to date have not been sufficient to satisfy regulatory requirements.

Increased emphasis is being placed by workers' health organizations in recent years identifying the risks posed to workers by noise and vibration. The effects of long-term exposure to noise and vibration are being quantified. The prime thrust of CANMET's R&D in this project is to evaluate the specific major noise and vibration sources affecting mine workers and to develop technology to reduce the health hazard through reduction of noise and vibration produced.

Planned Activity for 1986/87

a) This fiscal year focuses on the completion of noise reports on 1984 noise studies at Falconbridge and completion of reports on finger sensitivity tests at Stanleigh Uranium Mine.

# Radiation

Project Leader J. Bigu
(705) 848-2236

R. Tervo
(705) 848-2236

Objectives:

To establish a national calibration facility for instruments measuring radon, thoron and their decay products, to quantify by aspha- and gamma-spectroscopy long-lived radioactive dust and to develop and test radiation instrumentation and undertake radiation studies leading to control of radiation and better assessment of personal radiation dose exposure.

Background:

Radiation dose to uranium mine personnel can be controlled basically by limiting the time of exposure, protecting the worker (e.g. shielding), and by reducing the radiation level. Ventilation is an effective way of reducing radiation levels at working sites. However, there are other methods that may prove to be both effective and economical in helping to control and/or minimize radiation levels. Such methods include (1) coating mine walls with certain chemical agents (sealants to reduce radon/thoron) migration through mine walls; (2) use of mixing fans to eliminate decay products by plate-out on the fan blades and on wall surfaces to convective air currents set-up by the fan; (3) use, in certain cases, of special 'loose' filter materials with electret properties to remove decay products by mechanical trapping and electrostatic precipitation. The measurement of mine radiation levels and exposure dose to workers is of utmost importance from the health physics, occupational and engineering standpoints. Furthermore, reliable experimental radiation data very much depends on adequate performance of monitoring instrumentation. Hence, proper testing procedures and calibration of radiation instrumentation are important. In this light, the establishment of a large test facility for radon, thorin and their decay products is indispensible. Finally, the recommendations regarding limits of exposure to long-lived radioactive dust in relation to total dose exposure to external gamma-radiation and airborne alpha-emitters (i.e. radon and thoron daughters in the submicron and respirable range). Hence, identification and quantification of long-lived radioactive dust has become an important issue.

Planned Activity for 1986/87

a) Completed this year will be a combined study of radiation, dust and ventilation.

## Uranium Reserves

Project Leader Á. Füstös
(613) 996-4570 (X161)

Objective:

To determine and report annually on Canada's economically mineable uranium reserves and associated inferred resources. To determine the ore reserve of specified mineral deposits to meet departmental information requirements and to develop new ore reserve evaluation methodologies for the assessment of reserves and related economic evaluations.

Background:

The determination of uranium reserves and associated inferred resources in Canadian deposits was assigned to MRL/CANMET by Cabinet order in 1974. For reliable uranium resource and resource assessments it was necessary to obtain primary core drilling data from all companies with relevant deposits. Over the subsequent years this has been done. For computer storage of such data and the required assessment calculations and evaluations, it was necessary to develop two parallel sequences of reserve assessment computer programs (CADD and GEM). Over time this has been done and the complete set of programs are now being made available to the public.

Only economically mineable reserves and resources of uranium in Canada are included in confidential national reports, as the basis for annual published aggregated results. Accordingly, it has been necessary to estimate mining costs and conduct simple economic prices assigned by URAG, which are used to establish lower limit cutoff grades for reserve assessment.

Independently estimated mineable uranium reserves and resources are required as input to government (URAG) policy decisions on domestic and export quotas for Canadian utilities and uranium producing operations, as well as the granting of licences by AECB. In addition, projections of future Canadian uranium production by companies are queried internally, as well as in aggregated form for international agencies such as the International Atomic Energy Agency (IAEA).

Planned Activity for 1986/87

a) Periodic reports are done on Canadian uranium reserves deposit by deposit, including significant general information on the status of each.

b) Annually, a report of new computer-based methodologies for evaluating uranium and other mineral reserves and resources, including procedures utilizing conventional, geostatistical and global statistical multiple cutoff systems is produced.

## Fire and Explosion Hazard Research and Development

Project Leader E.D. Dainty
(613) 996-4570 (X149)

Objective:

To characterize the explosion hazard of ferro-silica and sulphide-ore dust and demonstrate the most promising technology to control sulphide-ore dust explosions in a Canadian mine. To develop a method for evaluating the thermite reaction hazard resulting from impact on light alloys and to establish a larger test chamber for characterization of dust explosion parameters.

Background:

CEAL (Canadian Explosive Atmospheres Laboratory) has been active since its inception in the field of accidental gaseous explosions and has established a reputation in that field. The dust explosion project was transferred to CEAL from CERL (Canadian Explosives Research Laboratory) in fiscal year 1985/86. However, delays beyond the control of CEAL have occurred in the renovation of the building to accommodate the dust explosion equipment. Hence, the commissioning of the new dust explosion laboratory will be in fiscal year 1986/87 rather than fiscal year 1985/86 as had been planned. The major thrusts during the next 2 years will be to investigate, on a laboratory and field basis, sulphide ore dust explosions which present a serious problem to several major Canadian mines.

Planned Activity for 1986/87

a) Due to be completed this year is the characterization of explosion hazard ferro-silica.

## Diesel Flameproof & Ventilation Research and Development

Project Leader E.D. Dainty
(613) 996-4570 (X 149)

Objective:

To demonstrate diesel emissions toxicity devices underground and to evaluate methane, diesel contaminant, ventilation and spontaneous combustion sensors for use in a continuous mine monitoring system.

Background:

CANMET/MRL/CEAL has been active for several years in the development of equipment to reduce the toxicity of diesel emissions because of the fear that productive diesel machinery was perceived by labour as posing a health hazard. This health-related work has been increasingly well-received, resulting in the world-leading role which CEAL has taken in this particular area because of the very large relative size of the Canadian underground dieselized fleet in all types of mines. This work will complete a major milestone in 1985/1986 with the underground testing of emissions reduction equipment developed under the USBM/MOL/CANMET collaborative agreement. Less emphasis will then be placed on diesel emissions equipment development and health impact studies. However, these efforts must continue in-house on a modest basis as a support to the diesel machinery certification processes which will need to expand because of the provincial inspectorates requirement for the certification of non-coal mining diesel machinery (where diesel usage is mainly concentrated in Canada). This requirement will be fully implemented when the CSA standard for diesel machines underground in finalized (B.C. requires this now).

The underground environment assessment work, which parallels the above development, has had two thrusts: (1) assessment of underground airborne samples in diesel environments for PAHs and mutagenesis, and (2) assessment underground of diesel environments for toxic gaseous and particulate concentrations providing an Air Quality Index (AQI) survey of Canadian mines. The research and development associated with the first has been virtually completed and the second will be completed and transferred to Elliot Lake by 31 March 1987. The 'wrapping up' of loose ends will be required in 1986/87 for both equipment development and environment assessment.

Planned Activity for 1986/87

a) A demonstration of diesel emissions reduction technology as well as an evaluation of continuous environmental contaminant sensors will be completed.

## Equipment Certification and Testing

Project Leader J.A. Bossert
(613) 996-4570 (X138)

Objective:

To provide, on a continuing basis, a certification service to Federal and Provincial Inspection authorities for apparatus and materials intended for use in underground gassy mines. To provide testing services in support of the certification service, as well as contract testing services to clients seeking evaluation of apparatus and materials for use in industries where explosive gas and/or dust hazards may exist.

Background:

The certification service was started in 1955 at the request of the Provincial Ministers of Mines who saw a need for a Canadian certification service for equipment and materials for use in underground coal mines. This service is provided to manufacturers or users on a cost-recovery basis. The major outputs are certificates issued (currently about 80 per year) and a published list of certified products.

Whenever possible, these certificates are based upon conformance with national consensus standards. Because of EMR's involvement as a certifying body, our input is required (as committee members) in a number of technical committees.

Because there is no other organization in Canada performing testing services in explosive atmospheres, this service is also made available to other Canadian companies and organizations on a cost-recovery basis.

Planned Activity for 1986/87

a) Produced, as required and requested, are certificates for flameproof and intrinsically safe electrical equipment, gas detection equipment, diesel powered equipment, fire resistant materials (conveyor belts, electric cables, hydraulic fluids, ducts and pipes) for use in underground gassy mines.

b) Test reports as related to the above apparatus and materials for gassy underground mines, in addition to other test reports relative to similar equipment used by other industries and test reports of special equipment for underground gassy mines and other industries will be provided.

# Quality Assurance

Project Leader J.A. Bossert
(613) 996-4570 (X138)

## Objective:

To monitor the continuing compliance of apparatus and materials certified by EMR after certification and to maintain a certification history of EMR certified products.

## Background:

In 1984, EMR and CSA (Canadian Standards Association) signed a Memorandum of Understanding which included a provision for CEAL to utilize CSA's extensive factory inspection network which operates on a world-wide basis. This has enabled CEAL to set up a system of programmed factory inspections to ensure that certified equipment and materials continue to meet EMR's requirements after the certificate has been issued.

## Planned Activity for 1986/87

a) A listing of all valid certificates is to be published annually; an inspection history is maintained for all certified apparatus utilizing a computer based data system.

b) Annual visits to all manufacturers holding regular certificates for equipment and materials for use in underground mines to ensure continuing compliance with the applicable standards or requirements.

## Standards Development

Project Leader J.A. Bossert
(613) 996-4570 (X138)

Objective:

To participate in the development of standards related to apparatus and materials for use in gassy underground mines through membership in Standards-writing committees and through related research and to foster international standardization of the relevant products.

Background:

As part of the equipment and materials certification for underground mines, Canadian standards are required in order that the certificates are based upon fair and reasonable requirements. CEAL participates in the writing of these standards by participation in technical committees operating on a National and International basis, and in addition, performs research studies on new test methods proposed in order to assist these committees in their deliberations.

Planned Activity for 1986/87

a) Draft Canadian standards are currently under preparation and eventually to be published as National Standards of Canada which will include mine ventilation materials.

   (flameproof diesel powered equipment and flameproof conveyor belting are completed drafts and currently under consideration by CSA technical committee)

b) International standards for electrical equipment.

## Tailings Management and Contaminant Migration from Tailings Pit

Project Leader N.K. Davé
(705) 848-2236

Objective:

To develop methods/technology for the management of mine/mill waste to reduce environmental impact of contaminant transport via surface run-off, subsurface seepage and surface erosion by wind and water.

Background:

The development of methods for the minimization of the environmental impact of mine/mill waste involves both laboratory and field investigations. The Elliot Lake Laboratory of CANMET is uniquely situated to undertake studies on the methods for the safe disposal of mine/mill wastes, surface stabilization by vegetative cover and environmental pathways for contaminants migration. The disposal technique may be the conventional land-based tailings management system in which the tailings surface and effluent will require treatment to reduce the effects of weathering and other natural forces. In some special cases, the disposal may be undertaken in keep lakes to minimize the oxidation of metal sulphides in which case the stability under the applicable conditions must be known. Suitability of vegetative cover and other chemical surface stabilization techniques have to be evaluated for land based management systems for their role in minimizing leaching, contaminant migration via surface and groundwater flow regimes and uptake of contaminants by plants and various other inhabitants of the waste management area.

CANMET's role will consist of the demonstration and evaluation of methods such as vegetating the tailings pile surfaces and other engineering cover techniques for monitoring their effectiveness and identifying and evaluating the mechanisms which tend to promote release of environmental contaminants from them through soil development, water movement and food chain pathways.

The knowledge acquired from these studies will assist Federal and Provincial government agencies in the formulation of policies for the development of their uranium resources which will permit enjoyment of their socio-economic benefits without leaving a legacy of environmental despoliation and human health hazards in the near future.

The base metals and uranium mining companies will benefit from the results of this project including provincial and federal governments through their financial holdings in some of these.

Planned Activity for 1986/87

a) A progress report will be prepared on solution transport and contaminants migration from tailings.

b) Also under preparation is a progress report on tailings stability using chemical methods.

# APPENDIX "A"

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|---|---|
| Contractor: | Mining Resource Engineering Limited |
| Scientific Authority: | K.K. Feng |
| Title: | Theoretical Model for Predicting Low Velocity Impact Sensitivity Bubble Sensitized Slurry Explosion |
| Contract Value: | $105K |

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|---|---|
| Contractor: | Mining Resource Engineering Limited |
| Scientific Authority: | K.K. Feng |
| Title: | Experimental Verification of High Velocity Impact Model for Slurry Explosives Projectile Impact |
| Contract Value: | $200K |

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|---|---|
| Contractor: | Mining Resource Engineering Limited |
| Scientific Authority: | R.R. Vandebeek |
| Title: | Evaluation of Propagation Sensitivity of Commercial Explosives in 15cm Diameter Hole |
| Contract Value: | $92K |

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|---|---|
| Contractor: | Cominco Limited |
| Scientific Authority: | G. Herget |
| Title: | To Carry Out Field and Laboratory Testing, Field Measurements and Numerical Modelling of Excavations in Potash |
| Contract Value: | $90K |

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Contractor: J.S. Redpath Limited

Scientific Authority: R. Clarke

Title: Estimated Preproduction and Operating Costs of Mining Small Mineral Deposits by Underground Methods (UP-R-237)

Contract Value: $131.15K

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Contractor: Vadeko International

Scientific Authority: J. Pathak

Title: Development, Construction and Testing of Prototype Accessories for Automation of Down-the-Hole Drill (UP-V-42)

Contract Value: $186.25K

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Contractor: Teledyne Canada

Scientific Authority: J. Pathak

Title: Determination of the Viability of Cavitating Hydro Impact (UP-T-223)

Contract Value: $249.90K

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Contractor: Mining Resource Engineering Limited

Scientific Authority: J. Pathak

Title: Computer Blast Design Program Evaluation for Large Diameter Blasthole Stopes Underground

Contract Value: $80.73K

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|---|---|
| Contractor: | Queen's University |
| Scientific Authority: | J. Pathak |
| Title: | Self Instruction Teaching Package for the Design and Application of Perimeter Blasting in Open Pit Mines |
| Contract Value: | $16.55K |

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|---|---|
| Contractor: | Denison Potacan Potash Company |
| Scientific Authority: | G. Herget |
| Title: | New Brunswick MDA: Use of Backfill in New Brunswick Potash Mines |
| Contract Value: | $214.74K |

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|---|---|
| Contractor: | Central Canada Potash |
| Scientific Authority: | S. Vongpaisal |
| Title: | Regional Subsidence Related to Potash Mining |
| Contract Value: | $50K |

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|---|---|
| Contractor: | McGill University |
| Scientific Authority: | D.G.F. Hedley |
| Title: | Research on Microseismic Technology |
| Contract Value: | $40K |

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|---|---|
| Contractor: | C. Mirz Engineering |
| Scientific Authority: | M. Bétournay |
| Title: | Sampling, Field Testing and Modelling of a Surface Crown Pillar, Les Mines Selbaie, Quebec |
| Contract Value: | $99.62K |

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|---|---|
| Contractor: | Noranda Research Centre |
| Scientific Authority: | D.G.F. Hedley |
| Title: | Development of a State-of-the-Art Microseismic Monitoring System (UP-N-204) |
| Contract Value: | $325K |

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|---|---|
| Contractor: | Dome Mines Limited |
| Scientific Authority: | C.B. Graham |
| Title: | Ontario MDA - Part I:<br>In Situ Determination of Dewatered Tailings Fill Properties in Ontario Mines |
| Contract Value: | $152.58K |

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|---|---|
| Contractor: | INCO Limited |
| Scientific Authority: | C.B. Graham |
| Title: | Ontario MDA - Part II:<br>In Situ Determination of Dewatered Tailings Fill Properties in Ontario Mines |
| Contract Value: | $112K |

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|---|---|
| Contractor: | Falconbridge Limited |
| Scientific Authority: | C.B. Graham |
| Title: | Ontario MDA - Task 2:<br>In Situ Monitoring and Computer Modelling of a Cemented Sill Mat and Confines During Tertiary Stage Pillar Recovery |
| Contract Value: | $154.72K |

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|---|---|
| Contractor: | Mining Resource Engineering Limited |
| Scientific Authority: | R.F. Boyle |
| Title: | Ontario MDA - Task 5:<br>Computer Programs Specifications for Ontario Mining Industry |
| Contract Value: | $50K |

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|---|---|
| Contractor: | Denison Mines Limited |
| Scientific Authority: | D.G.F. Hedley |
| Title: | Ontario MDA - Task 3:<br>Use of Consolidated Fills for Controlling Violent Pillar Failure in Ontario Mines |
| Contract Value: | $610K |

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|---|---|
| Contractor: | Falconbridge Limited |
| Scientific Authority: | C.B. Graham |
| Title: | Ontario MDA - Task 5:<br>In Situ Properties of Backfill Alternatives in Ontario Mines |
| Contract Value: | $470K |

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|---|---|
| Contractor: | To Tender |
| Scientific Authority: | Y.S. Yu |
| Title: | Ontario MDA - Simulation of Bulk Mining at Depth with Backfill in Ontario Mines |
| Contract Value: | $1, 000,000.00 |

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|---|---|
| Contractor: | Dome Mines Limited |
| Scientific Authority: | C.B. Graham |
| Title: | Ontario MDA - Task 7 - Part III: Liquefaction of Potential of Dense Backfill |
| Contract Value: | $111.25K |

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|---|---|
| Contractor: | Group-Conseil Roche Ltée |
| Scientific Authority: | M. Bétournay |
| Title: | Surface Crown Pillar Study - Phase II: Case Studies |
| Contract Value: | $150.12K |

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|---|---|
| Contractor: | Re/Spec Limited |
| Scientific Authority: | Y.S. Yu |
| Title: | GEOROC: Technology Transfer Seminars for the Potash Industry |
| Contract Value: | $13.50K |

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|---|---|
| Contractor: | Davis Engineering Limited |
| Scientific Authority: | J. Pathak |
| Title: | Design and Development of a Blasthole Depth Measurement Test Set |
| Contract Value: | $77.37K |

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|---|---|
| Contractor: | Sherritt Gordon Mines |
| Scientific Authority: | S. Vongpaisal |
| Title: | Manitoba MDA - Task 2: Ground Stability Evaluation with Reference to En Echelon Lensed Orebody |
| Contract Value: | $289.10K |

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|---|---|
| Contractor: | Sherritt Gordon Mines |
| Scientific Authority: | S. Vongpaisal |
| Title: | Manitoba MDA - Task 3: Communication System for Isolated Areas in Mines |
| Contract Value: | $429.40K |

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|---|---|
| Contractor: | INCO Limited |
| Scientific Authority: | Y.S. Yu |
| Title: | Manitoba MDA - Task 4: Geomechanical Data Base for Ground Control in Deep Mines |
| Contract Value: | $255.55K |

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|---|---|
| Contractor: | INCO Limited |
| Scientific Authority: | Y.S. Yu |
| Title: | Manitoba MDA - Task 1:<br>Develop Vertical Block Method Design Guidelines for Steeply Dipping Orebody Techniques |
| Contract Value: | $362.50K |

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|---|---|
| Contractor: | INCO Limited |
| Scientific Authority: | J. Pathak |
| Title: | Manitoba MDA - Part III - Task 5:<br>Optimization of Blast Design for Blasthole Mining Operators |
| Contract Value: | $260K |

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|---|---|
| Contractor: | Hudson Bay Mining & Smelting Company |
| Scientific Authority: | C.B. Graham |
| Title: | Manitoba MDA - Task 6:<br>Delayed Backfill Consolidation |
| Contract Value: | $100K |

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|---|---|
| Contractor: | Thompson & Neilson |
| Scientific Authority: | J. Bigu |
| Title: | The Development of a New Semiconductor Alpha Portable Detection System (UP-T-234) |
| Contract Value: | $20K |

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|---|---|
| Contractor: | Laurentian University |
| Scientific Authority: | P. Mogan |
| Title: | Determination of the PAH Partition Ratio and Nature of Mutagens Generated by Catalytic Purifiers |
| Contract Value: | $54.34K |

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|---|---|
| Contractor: | McMaster University |
| Scientific Authority: | P. Mogan |
| Title: | Examination of Impact of Polynuclear Aromatic Hydrocarbon Explosion in Underground Mines |
| Contract Value: | $31.96K |

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|---|---|
| Contractor: | INCO Limited |
| Scientific Authority: | P. Mogan |
| Title: | Examination of the 100% Methanol or Pilot Diesel Methanol Engine as a Power Source for Underground Mines |
| Contract Value: | $160.40K |

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|---|---|
| Contractor: | Engine Control Systems |
| Scientific Authority: | E.D. Dainty |
| Title: | Development of Wire Mesh Particulate Oxidizer Traps Using Full Additives (UP-E-183) |
| Contract Value: | $75.94K |

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|---|---|
| Contractor: | Ontario Research Foundation |
| Scientific Authority: | E.D. Dainty |
| Title: | Compilation of Systems Development and Adaptation Phase of CANMET Diesel Emissions Reduction Program - Part III |
| Contract Value: | $81.63K |

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|---|---|
| Contractor: | McGill University |
| Scientific Authority: | K.J. Mintz |
| Title: | Determination of Turbulence Effects on the Severity of Dust-Air Explosions |
| Contract Value: | $50K |

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